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Specification and Drawings as originally filed, with Application for Patent Serial No: **2,391,681**, on June 26, 2002, by **STAR HEADLIGHT & LANTERN CO. OF CANADA LTD.**, assignee of John W. Toulmin, for "Solid-State Warning Light With Microprocessor Controlled Excitation Circuit".

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January 14, 2005

Date

Canada

(CIPO 68)
31-03-04

OPIC CIPO

The present invention relates generally to warning lights, and more specifically, to solid-state (LED) warning lights excited by inductive circuits and microprocessor controlled. Distribution pattern of light from the LEDs is controlled by light-control-film.

Background of the Invention

Warning lights are useful and desirable on many types of vehicles, machinery, and other objects (buildings, towers, people, animals, etc.) to announce the presence, location, operation mode, status, or function of the vehicle or machine or object.

The nature of warning lights requires them to be employed in harsh physical environments, often in remote or difficult-access locations, and with limited availability to electrical power.

Solid-state Light Emitting Diodes (LEDs) are well-suited to use in warning lights due to characteristics like good efficiency, small size and weight, rugged construction compared to other light sources like incandescent bulbs, etc.

However, existing LED warning lights suffer from a number of problems, including the following: circuit complexity (resulting in high production cost and poor reliability), low electrical-to-luminous power conversion efficiency (resulting in unwanted higher operating temperatures and unwanted higher electrical power consumption), and limited ability to operate from a range of electrical supply voltages.

In particular:

- LED constant voltage circuits require the use of series resistors, causing unwanted loss of electrical power as heat;
- LED constant current circuits require the use of additional circuitry to measure and control electrical power exciting the LED; and
- unregulated circuits require heat producing series resistors and are limited to operation over a narrow range of electrical supply voltages therefore limiting their application.

There is therefore a need for an improved LED warning light.

Summary of the Invention

Most light sources (including LEDs) require a means to control the direction and intensity of the emitted light. Light-control-film (LCF) may be used to reflect and refract light from the LEDs into useful patterns.

LEDs may be selected which contain optical lenses integral with the body of the LED package and so may not require the use of additional lenses or reflectors to focus the emitted light.

LEDs require a controlled electrical power source for operation.

LEDs can be operated most efficiently by an inductive excitation circuit. An inductive excitation circuit can be monitored and controlled by a microprocessor.

The pulsed direct-current nature of the inductive excitation circuit enables operation from a wide range of electrical supply voltages (and therefore can be operated from a wide range of electrical supplies (ex. Battery, solar panel, automotive electrical system, etc.).

A microprocessor can perform measurements on various environmental factors affecting the warning light (such as electrical supply voltage, ambient temperature, etc.) and automatically adjust its operation according to need.

A microprocessor can also send and receive information from a remote control or through a communications channel so as to make the warning light part of a network. As part of a network the warning light can receive commands to alter its operation, or transmit data from various sensors (environmental factors) or about its own status. Communications between the new warning light and a remote control or network may be implemented by a single or multi-wire interface or over a wireless link such as infrared(IR) or radio frequency(RF) link.

Other approaches in the art utilize light sources like incandescent or halogen bulbs, xenon flash tubes, or LEDs excited by other means.

LEDs can be excited by several other means:
-constant voltage regulated circuits with series resistors
-constant current regulated circuits
-unregulated circuits with series resistors

The invention addresses a number of problems in the art, including the following problems noted above:

- other LED excitation methods suffer from problems like; additional circuit complexity (resulting in unwanted higher production cost and poorer reliability), lower electrical-to-luminous power conversion efficiency (resulting in unwanted higher operating temperatures and unwanted higher electrical power consumption), and limited ability to operate from a range of electrical supply voltages
- LED constant voltage circuits require the use of series resistors causing unwanted loss of electrical power as heat
- LED constant current circuits require the use of additional circuitry to measure and control electrical power exciting the LED

- unregulated circuits require heat producing series resistors and are limited to operation over a narrow range of electrical supply voltages therefore limiting their application.

Lenses and reflectors can be expensive to manufacture and have size and shape characteristics that limit their application. The light-control-film used in the invention is thin, rugged and flexible, and can be easily worked to produce a wide variety of light control effects.

The new warning light may be used in many of the traditional warning light applications but with the benefit of reduced electrical power consumption, lower initial cost, improved reliability and longer life.

Additionally, the new warning light may find new applications enabled by its improved functional characteristics.

Reduced power requirements allow longer running time and/or increased light output in applications such as battery or solar powered marine installations.

Reduced initial cost and maintenance requirements improve the economic feasibilty of use of the new warning light in cost sensitive and access-restricted environments.

The ability to communicate over a network allows the new warning light to respond in useful ways to instructions from a remote source or to automatically adjust its own operation to changes in its operating environment in co-operation with other devices on the network. Examples: a controlled reduction in output power during periods of scarcity of the electrical power supply (batteries, solar cells, grid brown-out), or an organized increase in power output during times of increased need (impaired atmospheric visibility).

An array of the new warning lights may be assembled into a single housing for use on the roof of a service vehicle to replace the functionality of a "light bar". The network capability of the array simplifies the installation and maintenance by eliminating the large and heavy bundle of cables traditionally used to control a "light-bar".

Detailed Description of the Invention

A circuit which addresses the objects outlined above, is presented as a block diagram in Figure 1. This figure presents the schematic drawing of LEDs excited by an inductive switch-mode boost circuit controlled by a microprocessor. This circuit may be operated from supply voltages where the sum of the LED junction voltage drops is greater than the supply voltage.

All components and circuitry may be constructed on a single printed-wiring circuit board and is referred to as an Integrated LED Module (ILM).

-Q1 should be a transistor with the characteristic of low on-state resistance (much less than one ohm)

-L1 should be an inductor with low resistance and high inductance value (highest Q factor practical).

-D1 to DN should be a series branch of LEDs of high output luminous flux and capable of high current operation. The number of LEDs should be chosen so as to have a cumulative forward junction voltage drop higher than the supply voltage.

-U3 microprocessor (or microcontroller) should be of low power consumption and with suitable output pin drive capability to reliably assert the control pin of transistor Q1 alternately from off-state to on-state.

-U1 represents an over-current protection device and may be a suitably rated positive-temperature-coefficient fuse.

-U2 represents a low-power voltage regulator to provide a suitable current supply for the microprocessor.

-U4 represents an Analog-to-digital convertor used to detect and measure the electrical supply voltage. This information is used by the microprocessor to adjust pulse duration and pulse repetition rate used to excite the LEDs

-the microprocessor may use software look-up tables or an algorithm to determine the optimum pulse timing to apply to the LED excitation circuit

-the microprocessor alternately switches transistor from off-state to full conduction on-state at rate of approximately 100 KHz (design frequency can be chosen over a broad range to match choice of inductors and LEDs).

-the high pulse rate (approximately 100KHz) of the LED excitation circuit results in a visual effect of apparent constant illumination. An observer has no impression of pulsation of the LEDs emitted light.

-during the transistor Q1 on-state current flow increases through the inductor L1 to the common node, developing an electromagnetic field in the inductor Q1. No conduction occurs through the LEDs D1-to-DN.

-during the transistor Q1 off-state current flows through the inductor L1 and LEDs D1 to DN causing light to be emitted.

-a repetition rate should be chosen so as to allow the electromagnetic field in L1 to completely collapse and all current flow through the LEDs to cease before starting a new Q1 on-state.

-a discrete rectification diode is not employed as this function is performed by the LED junction(s).

-an output filter capacitor is not employed as there is no requirement for voltage ripple smoothing.

-the microprocessor may excite the LEDs in bursts so as to produce obvious pulses of light. The bursts may be of very short duration so as to give the appearance of a "strobe-light" or in longer duration bursts so as to produce a blinking or flashing effect.

-the microprocessor may receive commands via a data-communications network to start, stop or change its operation (for example, changing from strobing effect to flashing effect.)

-the microprocessor may automatically alter operation in response to changing environmental conditions sensed by the ILMs on-board sensors. (for example, reducing power output in response to low battery voltage.)

Figure 2 shows a circuit for operation where the sum of the LED junction voltage drops may be less than the supply voltage. U5 represents a voltage level shifting device to bias the transistor.

Figure 3 and Figure 4 show circuits where an LED module (LM) may be separate from the control module containing the microprocessor and excitation circuitry (CM).

Figure 8 shows the simplest embodiment of the invention. A rugged, lightweight housing of extruded aluminum alloy with anodized surface and a clear, colourless polycarbonate lens protects an Integrated LED Module (ILM). Silicone gaskets provide weather-resistant joints between housing and lens and cable entry. Selectively applied Light Control Film (LCF) refracts light emitted by the LEDs to modify the viewing angle. A multi-conductor cable may provide electrical power and connections to a data-communications network.

Figure 7 shows an ILM assembly in cylindrical form. This assembly may be constructed with conventional low-cost Printed Wiring Circuit Assembly techniques. The cylinder is formed by attaching LED sub-assemblies to a base circuit board by means of multi-pin right-angle pin headers that provide both mechanical and electrical connection between the circuit boards. This construction technique allows the assembly of an omni-directional warning light module without the need for costly flexible or bendable circuit board materials.

Figure 9 shows a rectangular embodiment consisting of four ILMs in a common housing. Housing may be rectangular or cylindrical or any suitable shape. Light emitted by the LEDs is refracted through 360 degrees by the LCF to form an omnidirectional beacon. Rechargable electrical storage battery located in the center of the assembly can provide electrical power for the ILMs. A Solar Panel mounted onto or forming the top of the housing may provide electrical power for the ILMs or to recharge the battery. A wireless radio-frequency or infrared link may provide connection to a data communications network. Such an assembly may operate for a years of time without any wired connections.

Figure 10 shows a linear assembly of ILMs in common housing. ILMs may contain LEDs of different colours and so be capable of replacing so-called "light -bars" used to signal vehicle identity and operation by means of colour codes (for example, Red and White indicating Police, Ambulance, Fire equipment or Blue indicating Snow removal equipment, etc.) .

Figure 11 shows the construction of an LED module consisting of an array of omnidirectional side-emitting LEDs.

Figure 12 shows the construction of an LED module consisting of an array of LEDs with optical lenses. The array is constructed so as to control the field-of-view.

Addressing the prior art disadvantages:

Glass lenses have the undesirable characteristics of being bulky, heavy, expensive and fragile.

Plastic lenses are also bulky and have poorer light transmission characteristics. Injection-moulds for plastic lens have high initial cost.

Reflectors tend to be large and bulky and their geometry favours the use of single point-source light types.

Purely resistive LED circuit - poorest efficiency - most electrical energy wasted as heat.

Current regulated LED circuit requires series current-sense resistor and sensitive analog-to-digital conversion circuit (undesirable high parts count) - expensive and complex to build.

Voltage regulated LED circuit have the combined unwanted characteristics of resistive and constant current-regulated schemes.

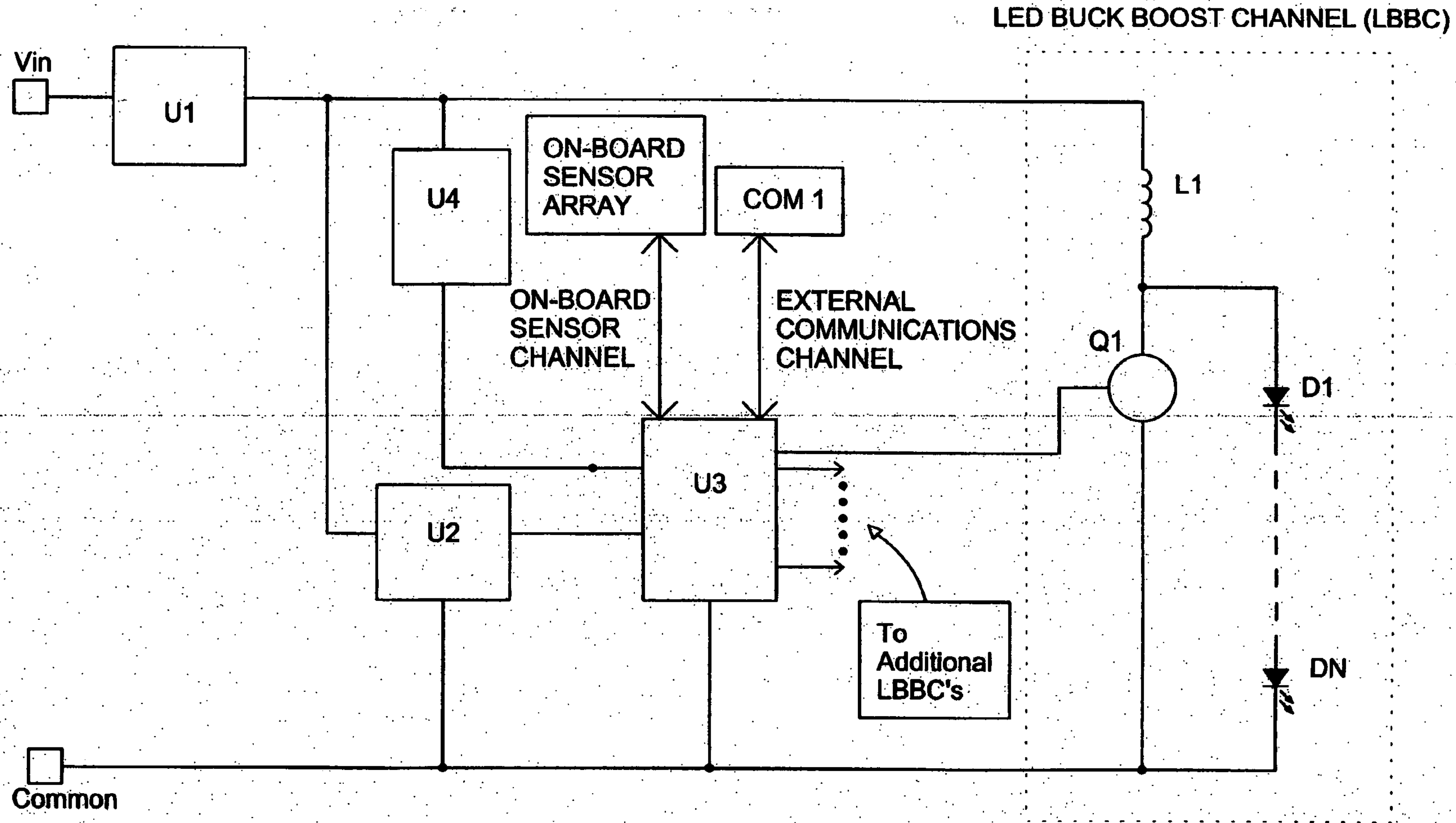
While particular embodiments of the present invention have been shown and described, it is clear that changes and modifications may be made to such embodiments without departing from the true scope and spirit of the invention.

EMBODIMENTS OF THE INVENTION INCLUDE:

- a microprocessor controlled excitation circuit for LEDs in warning lights.
- an inductive excitation circuit for LEDs in warning lights.
- a microprocessor controlled inductive excitation circuit for LEDs in warning lights.
- the inductive excitation circuit identified above, which can be configured to drive individual LEDs or many LEDs in series or parallel or combination series/parallel .
- an inductive excitation circuit which uses no capacitors, rectification diodes or resistors.
- an inductive excitation circuit which can be operated from a wide range of electrical supply voltages.
- a warning light having a microprocessor controlled excitation circuit, and means for communicate with other external devices.
- a warning light constructed of LED(s) and a microprocessor controlled excitation circuit, the microprocessor also having means for communicating over a network.
- a microprocessor-controlled warning light, having an on-board sensor array, allowing the microprocessor to adapt to environmental conditions.
- a microprocessor-controlled warning light, having an on-board a time-of-day clock and calendar allowing the warning light to modify operation in response to diurnal and seasonal requirements.
- a microprocessor-controlled warning light, having an on-board sensor array, allowing the microprocessor to modify the operation of the warning light in response to environmental conditions
- the on-board sensor array as defined above, including sensors from the group of: ambient temperature, internal temperature, ambient light, emitted light, relative humidity, liquid moisture, mechanical tilt and vibration and shock,

marine wave height and period, air pressure, solar cell voltage, and supply voltage sensors.

- Light-control-film used instead of lenses or reflectors to direct and focus light, allowing low-cost planar printed circuit assemblies to replace expensive and complex curved or circular assemblies.
- a cylindrical warning light consisting of a plurality of separate LED sub-assemblies on rigid printed circuits, attached to a base circuit board by means of multi-pin right-angle pin headers that provide both mechanical and electrical connection between the circuit boards, allowing the assembly of an omni-directional warning light module without the need for costly flexible or bendable circuit board materials.
- a cylindrical warning light consisting of a plurality of separate LED sub-assemblies on rigid printed circuits, attached to a base circuit board at substantially right-angles.
- a multi-directional warning light consisting of a plurality of separate LED sub-assemblies on rigid printed circuits, attached to a base circuit board such that the separate LED sub-assemblies are aimed in different directions.
- a multi-directional warning light consisting of a plurality of LED sub-assemblies on rigid printed circuits, these rigid printed circuits being connected to one another such that the separate LED sub-assemblies are aimed in different directions.
- a warning light having selectively applied light control film
- a warning light having a solar cell
- a warning light having a rechargeable storage battery
- a warning light having a linear assembly of LED modules, containing LEDs of different colours.
- a warning light having a microprocessor to provide separate control signals to separate LED sub-assemblies.
- a warning light having a plurality of layers of LED sub-assemblies, each LED sub-assembly having side-emitting LEDs.



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Title: LBBC ILM Schematic			
Size: A	Document Number: Sch1 T://LED Patent/PatentApp1		Rev: A
Date: Tuesday, June 04, 2002	Sheet 1 of 2		

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Figure 1.

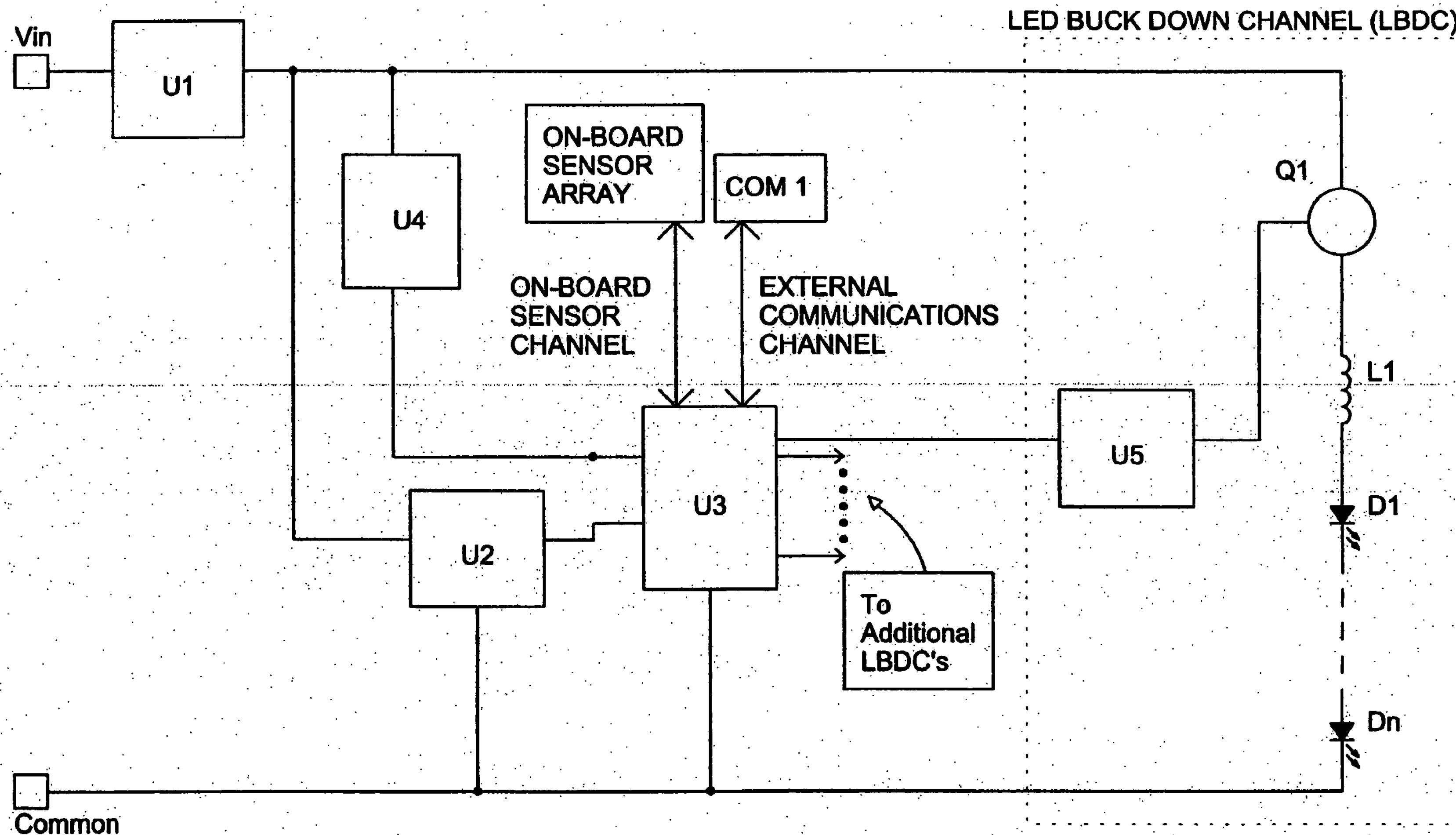

Figure 2.

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Size: A	Document Number: Sch2 T://LED Patent/PatentApp1	Rev: A
Date: Wednesday, June 12, 2002	Sheet 2 of 2	

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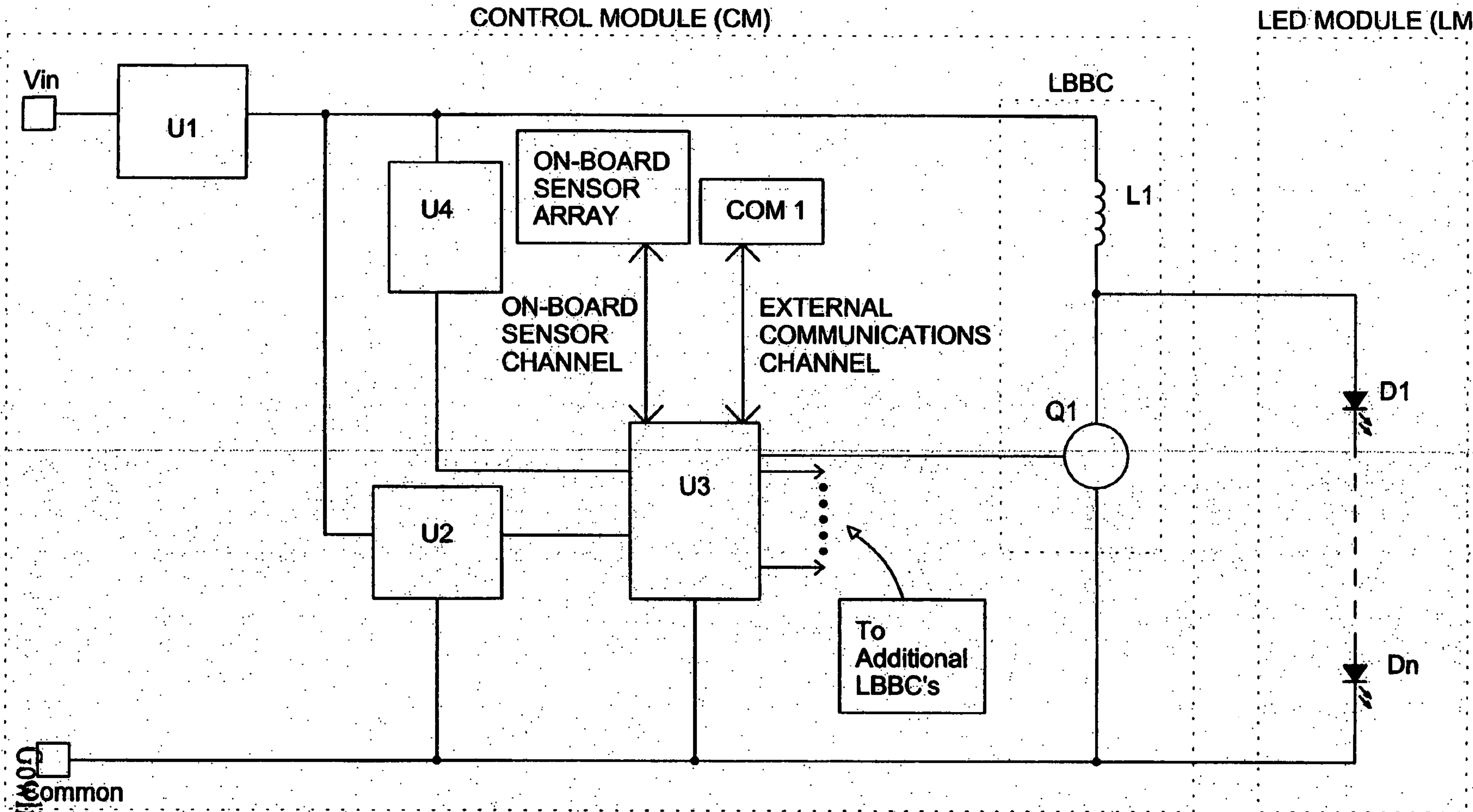

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Title: LBBC CM-LM Schematic		
Size: A	Document Number: Sch3 T://LED Patent/PatentApp2	Rev: A
Date: Tuesday, June 04, 2002	Sheet 1 of 2	

Figure 3.

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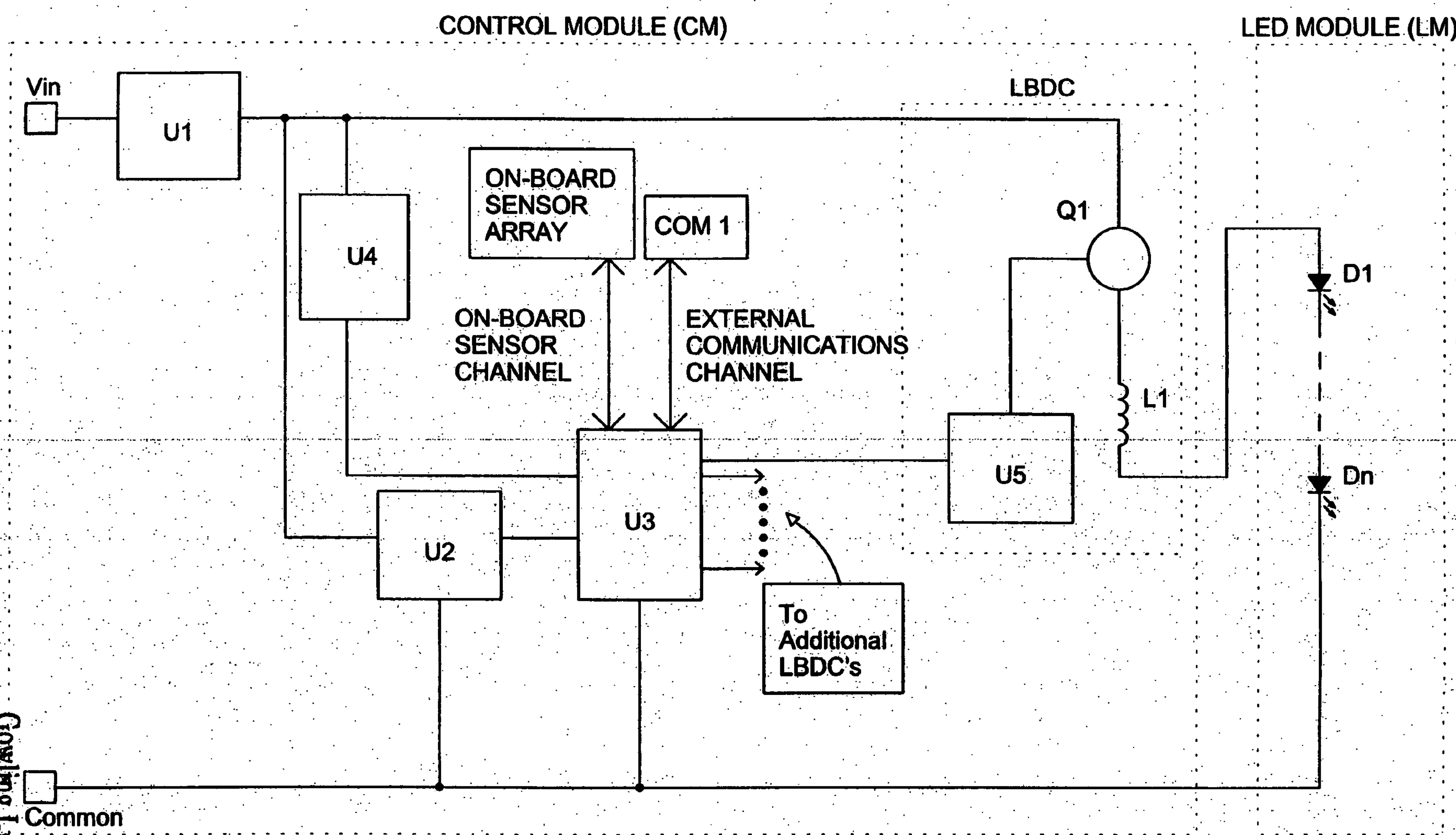

Figure 4.

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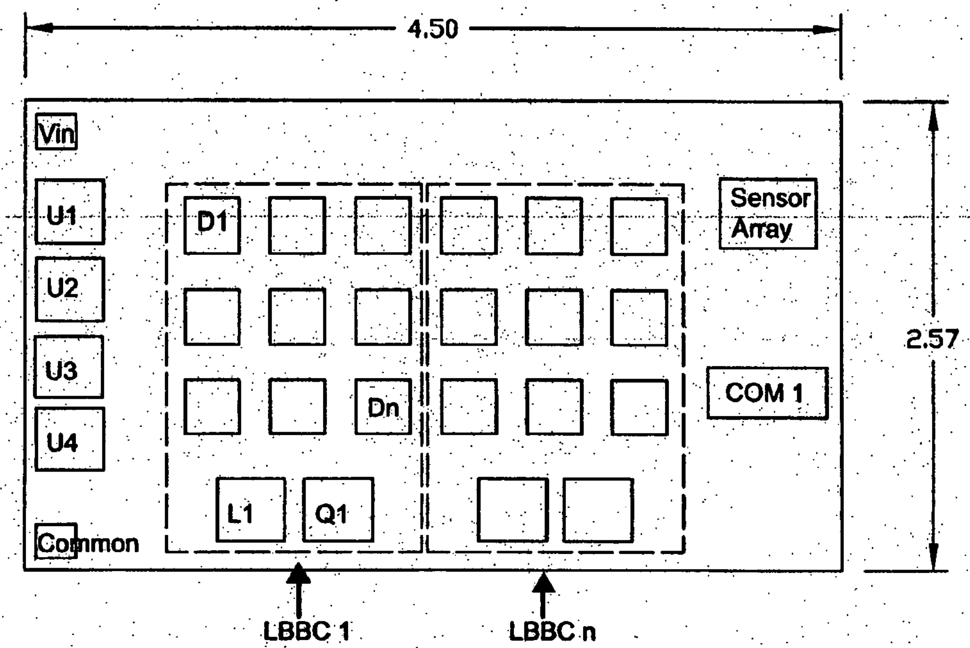
Size A	Document Number Sch4 T://LED Patent/PatentApp2		Rev A
Date:	Tuesday, June 04, 2002	Sheet 2 of 2	



STAR HEADLIGHT OF CANADA
PLANAR WARNING LIGHT MODULE LBBC ILM
Doc. Number Assy1
File: T://LED Patent/Assy1
Date: February 1, 2002

Figure 5.

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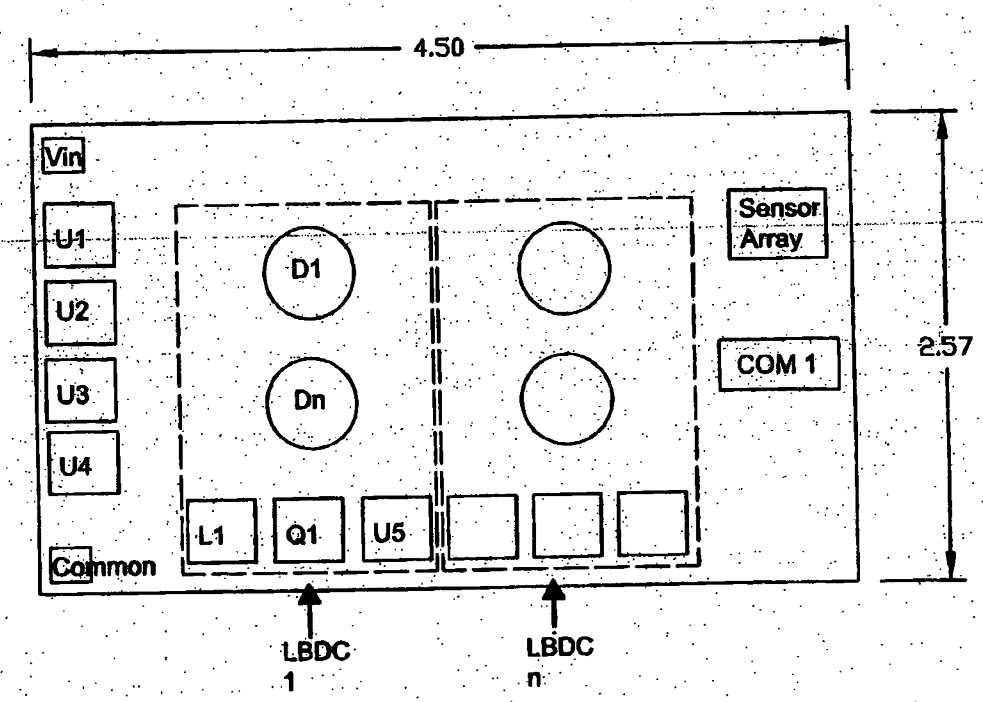

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PLANAR WARNING LIGHT MODULE LBDC ILM
Doc. Number Assy2
File: T://LED Patent/Assy2
Date: February 1, 2002

Figure 6.

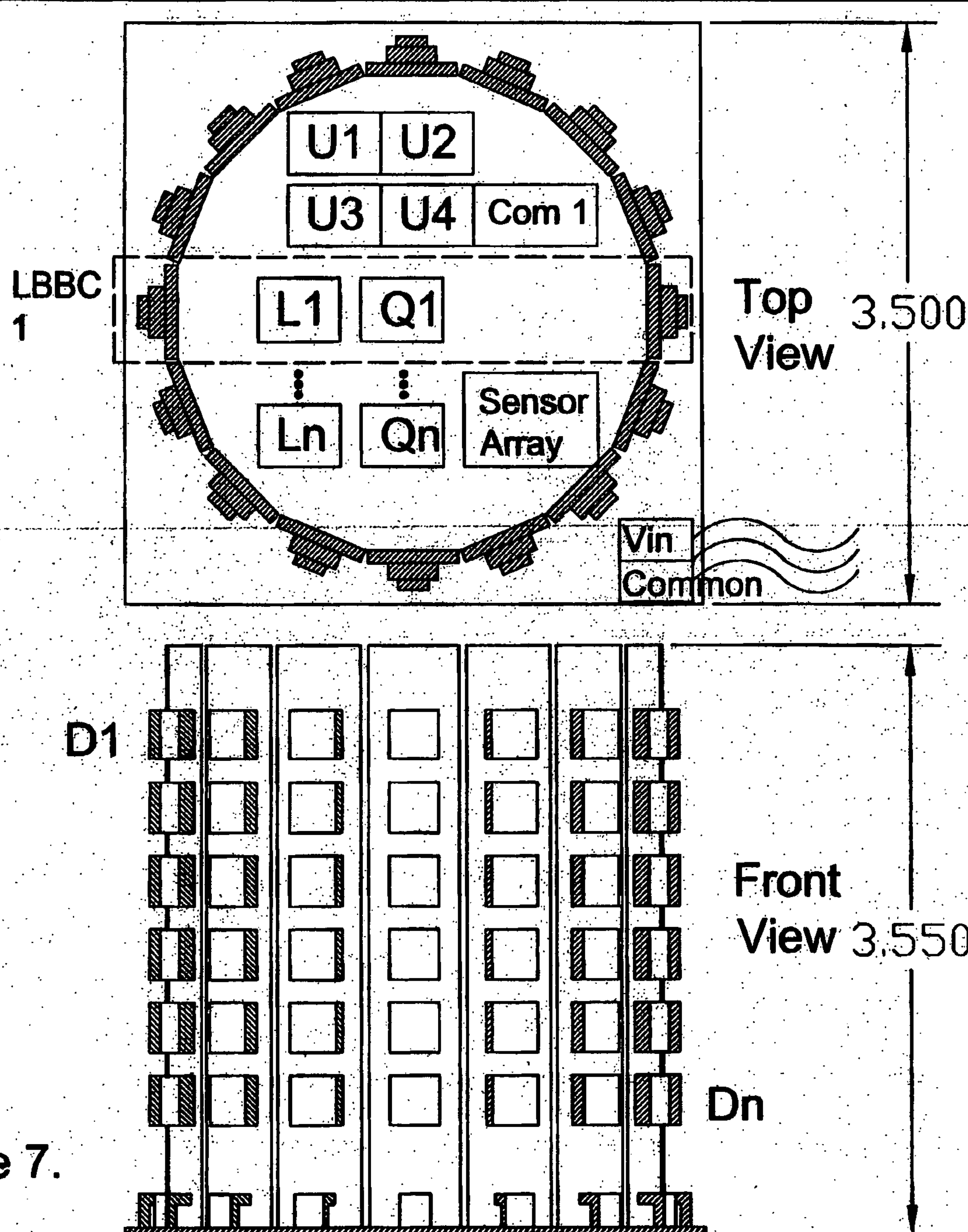

Figure 7.

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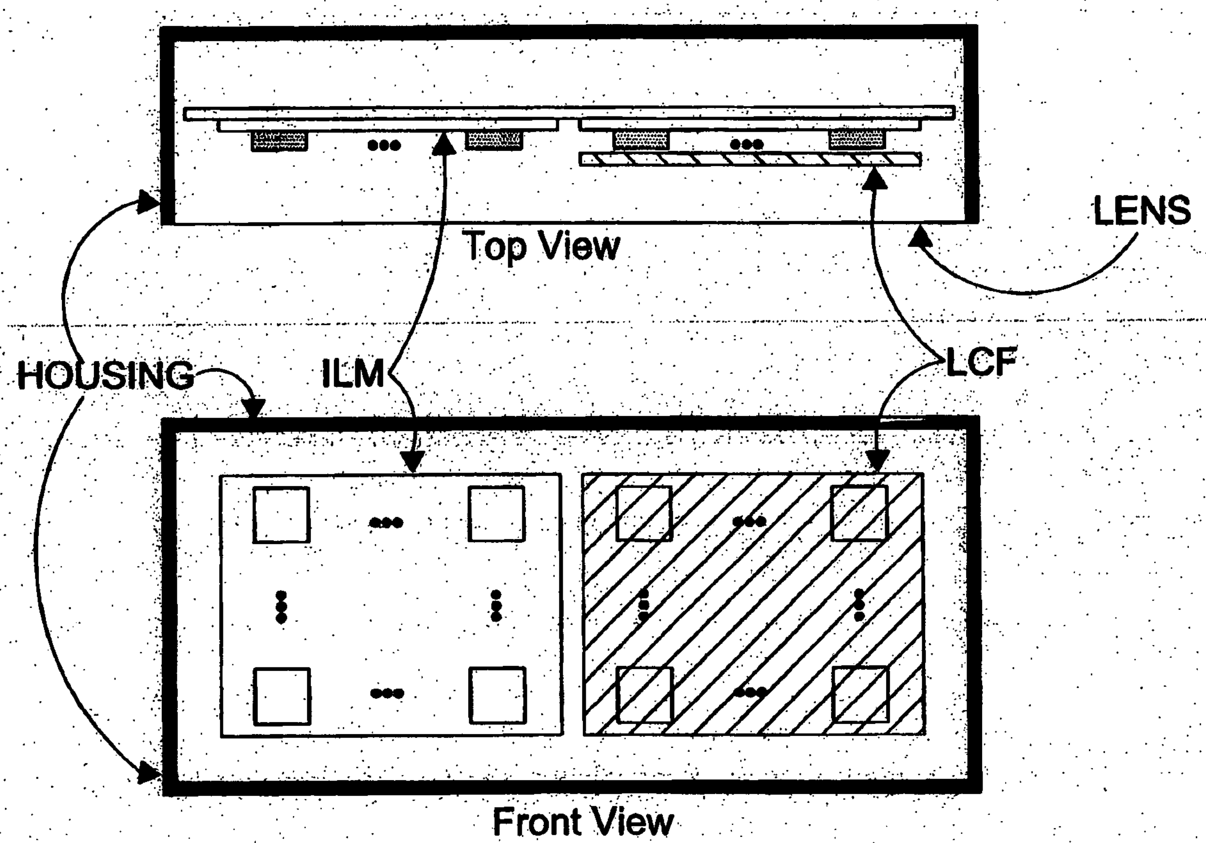
LED CYLINDRICAL WARNING LIGHT MODULE
LBBC ILM

Doc. Number
Assy500-3

File: T://LED Patent/Assy500-3

Date: September 1, 2001



STAR HEADLIGHT OF CANADA
MECHANICAL/OPTICAL ASSEMBLY DRAWING
Doc. Number ILM Assy 1
File: T://LED Patent/ILM_Assy_1
Date: January 10, 2002

Figure 8.

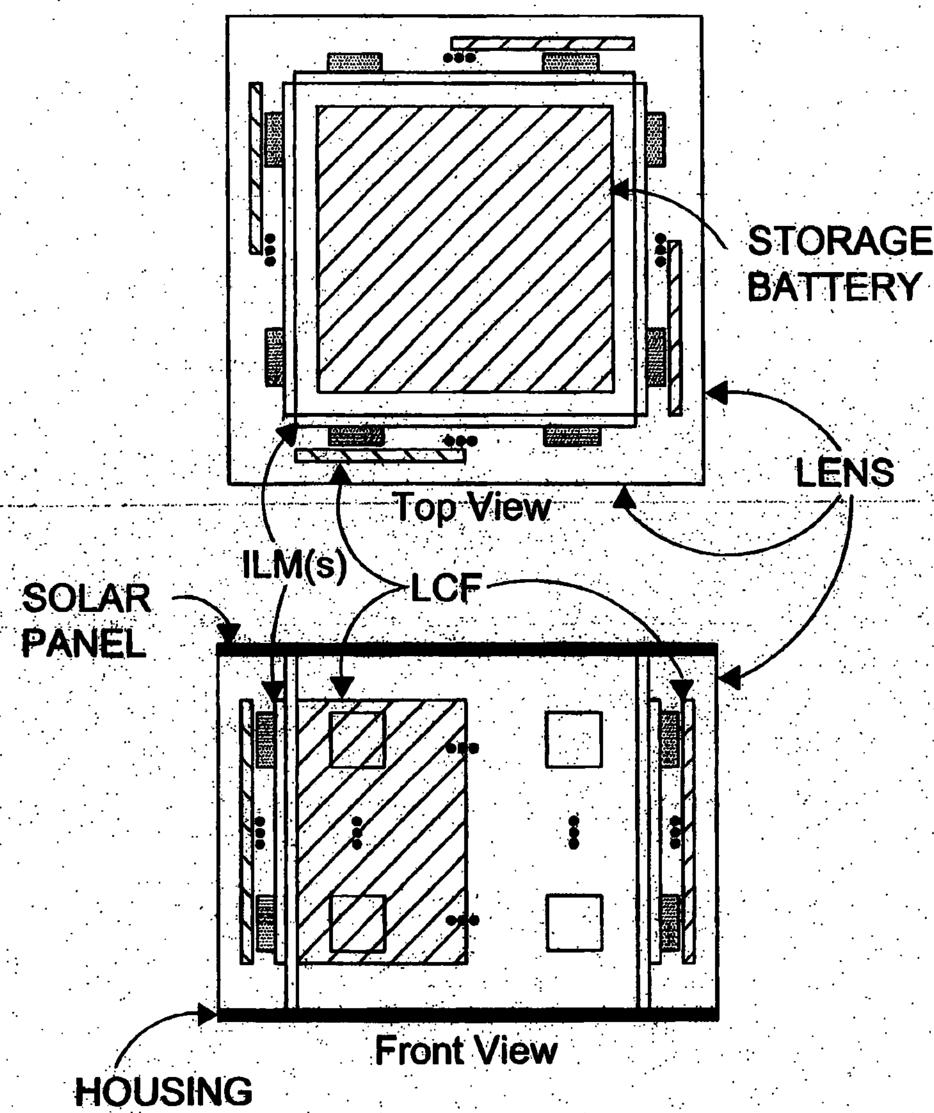


Figure 9.

STAR HEADLIGHT OF CANADA	
MECHANICAL/OPTICAL ASSEMBLY DRAWING	
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File: T://LED Patent/ILM_Assy_3	
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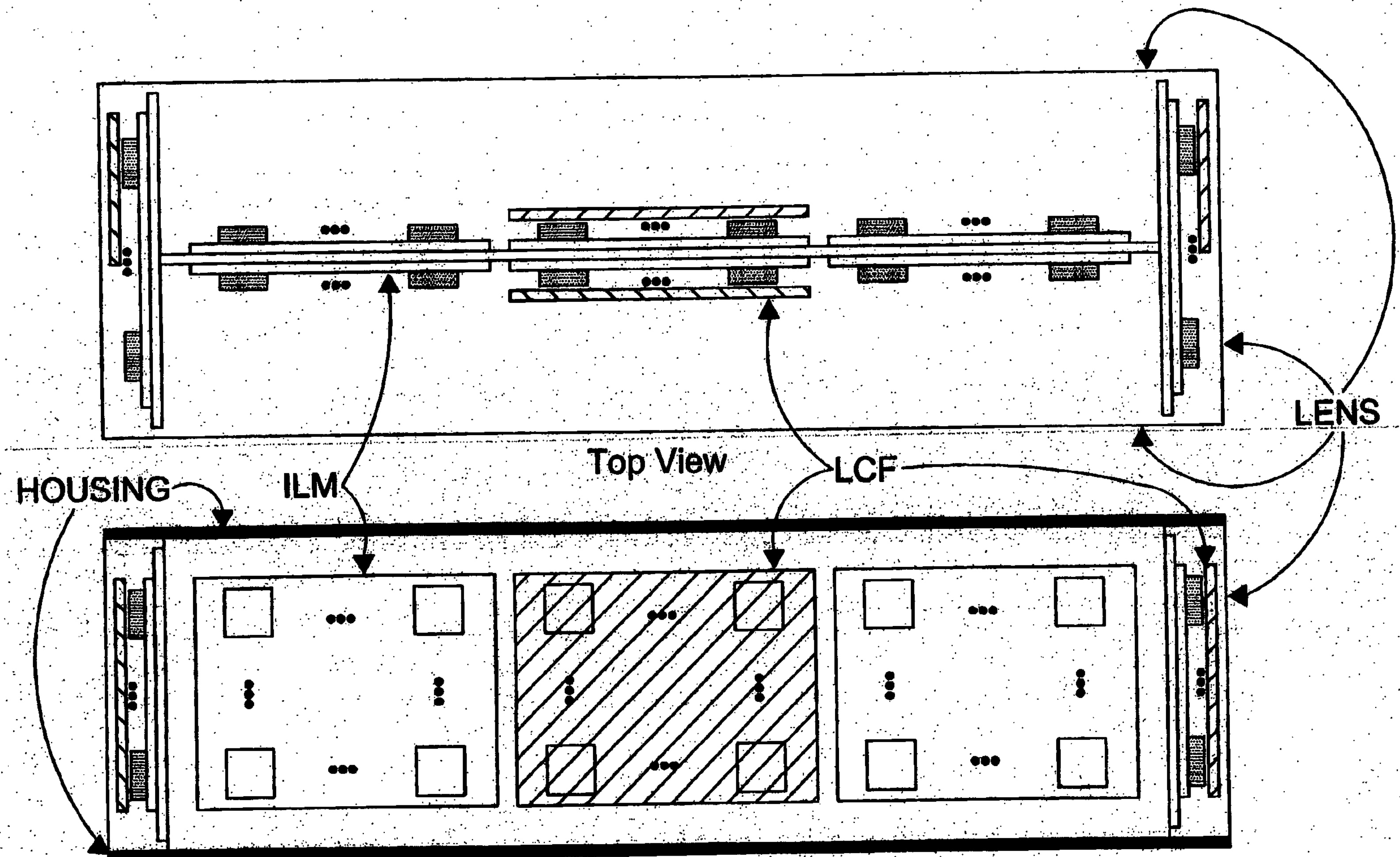

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MECHANICAL/OPTICAL ASSEMBLY DRAWING	
Doc. Number ILM Assy 2	
File: T://LED Patent/ILM_Assy_2	
Date: January 10, 2002	

Figure 10.

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED

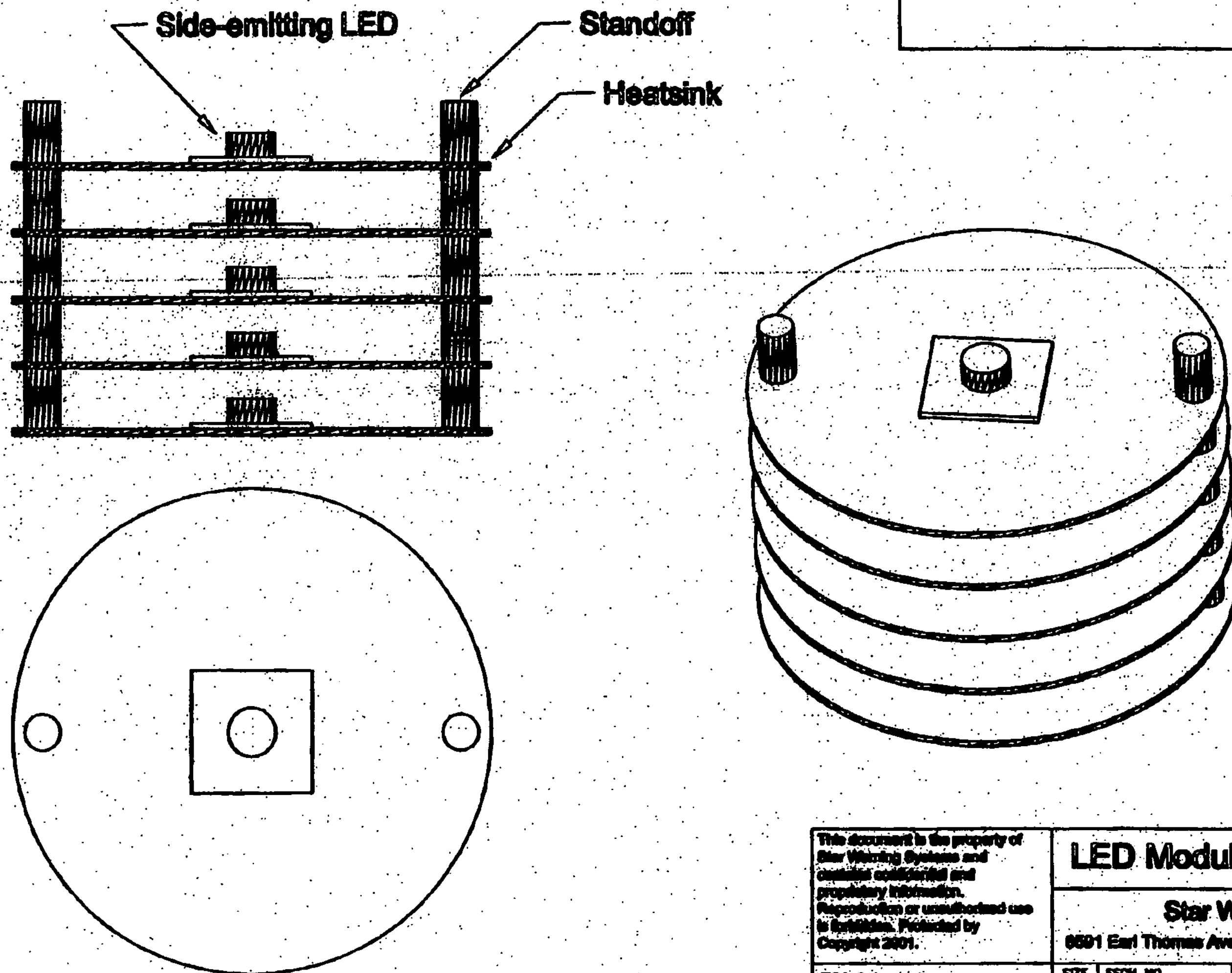

Figure 11.

F/N: 3views.dwg

LED Module (Side-Emitting)

Star Warning Systems

6591 Earl Thomas Ave. Niagara Falls Ontario Canada L2E 6X3

SIZE	FSCM NO.	DWG NO.	REV
SCALE		SHEET	

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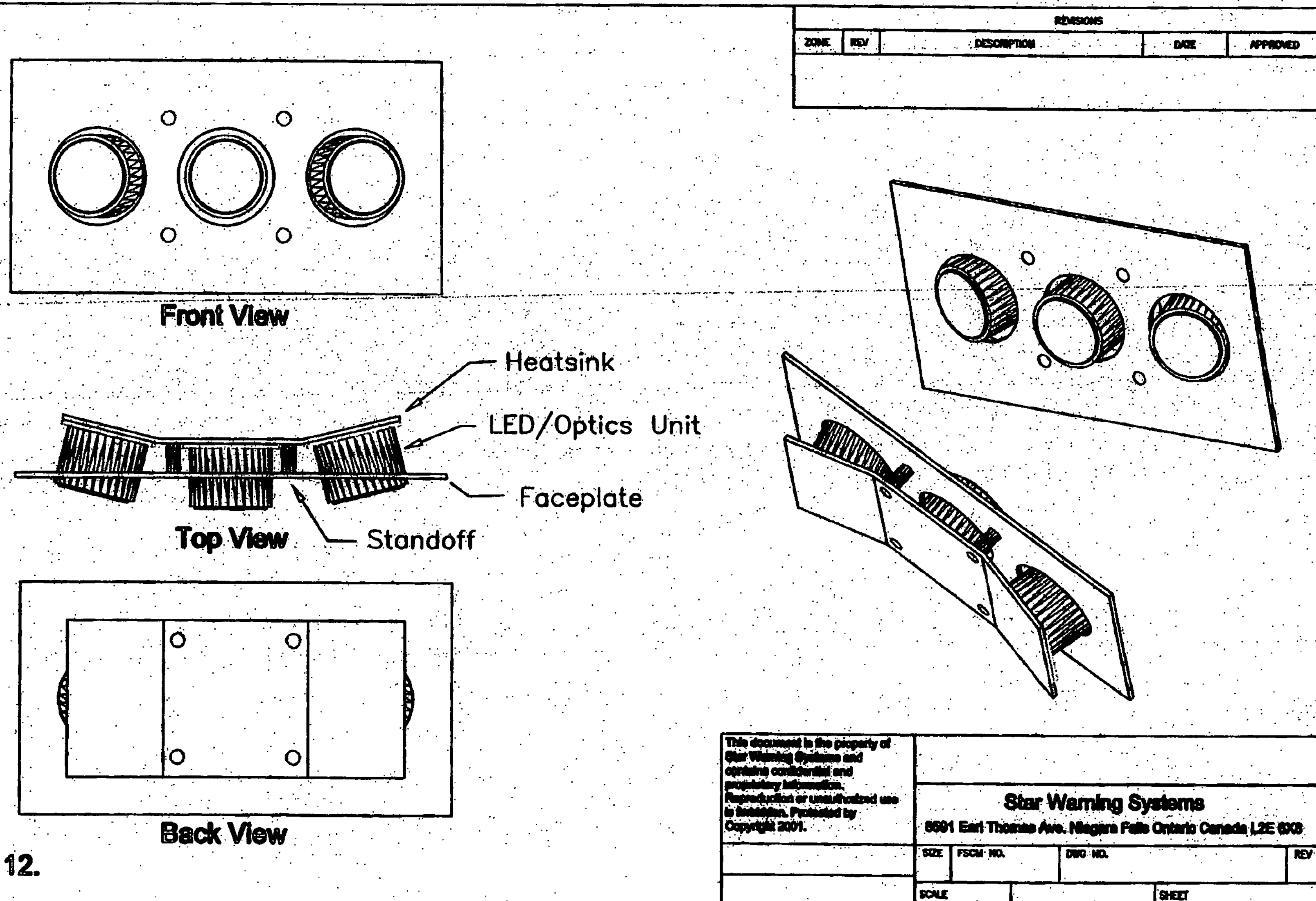
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Figure 12.